the exact location of the defaced numbers. To narrow down the locations, the entire defaced area was divided into three sections as shown in FIG. **31**, and each section analyzed to possibly recover some of the defaced numbers and use that as a guide to pinpoint the location of the defaced numbers.

From the still intact numbers on the engine block, it was determined that the VIN numbers were 5-2-5-1-[ ]-0-[ ]-4-1 with the square brackets indicating the completely defaced numbers. Knowledge of some of the serial numbers allowed for the evaluation of the identification process using only the defaced fork numbers.

An initial assessment of each section was carried out using the LIT and PCA processes as described above to investigate the possibility of locating regions where a number may have been and use this as a template to locate the positions of other numbers in the area.

A score image of the initial assessment of the middle section in FIG. **31** is shown in FIG. **32**. This score image shows what appeared to be parts of numbers that were not fully defaced allowing for their locations to be identified. The center to center distance between each of the possible numbers was determined for use as a guide to the possible positions of the other numbers. This distance was approximately 125 pixels wide. The bounded regions (white boxes in FIG. **31**) were extracted from the dataset and independently re-analyzed by PCA to characterize the local zones of plastic strain and recover the defaced numbers within.

A PCA assessment of the first section produced an area in a PC score image that could conceivably be identified as the zone of plastic strain beneath a defaced number. This area was extracted as a region of interest within the bounds of the white box shown on the image in FIG. **33** and re-analyzed independently. The center to center distance previously determined from the assessment of the middle section was used to determine the center of the next two numbers in the image to form the regions of interest (dark boxes in FIG. **33**) to also be re-analyzed independently by PCA.

The initial PCA assessment of the third section from FIG. **31** can be seen in FIG. **34**. A characteristic shape that may represent a local zone of plastic strain was identified and the region of interest localized (white box in FIG. **34**). This localized area was used to determine the possible locations of other numbers in this section (dark boxes in FIG. **34**) via the center to center distance determined from the defaced numbers in FIG. **32**.

Each of the localized regions of interest were independently analyzed using PCA to characterize and enhance the local thermal gradients around the defaced numbers. FIG. **35** shows the score images for the different areas. These images selected by visual inspection of all the 16 score images developed for each local region of interest across each of the four modulation frequencies (a total of 64 comparisons) showed enough detail to mark out a possible number. As with the gun barrel and needle holder, only one score image showed enough of such details with the other score images partially characterizing the number. These score images showing details of the defaced number were usually among the higher PC score images detailing how small the changes in thermal gradient are due to thermal conductivity differences within these regions. The following are the known stamped numbers from the engine block, the numbers also defaced on the engine block are labeled unknown:

a) 5 (0.03125 Hz),
b) 2 (0.03125 Hz),
c) 5 (0.03125 Hz),
d) 1 (0.05 Hz),
e) unknown (0.05 Hz),
f) 0 (0.05 Hz),
g) unknown (0.05 Hz),
h) 4 (0.05 Hz),
i) 1 (0.05 Hz)

Similar to the gun barrel and needle holder, thermal images collected at all four modulation frequencies captured enough of the thermal gradient to characterize the zone of plastic strain allowing for possible recovery of the defaced numbers. However, due to the differing depths of defacing, there were slight differences in the quality of the characterized zone of plastic strain.

From the score images of the defaced areas, PCA appeared to capture the variation in thermal gradient within the zones of plastic strain and heat affected zones, characterizing them into the score images. However, the small changes in thermal gradient between defaced regions and clean non-defaced regions, as well as general surface conditions from defacing the serial numbers reduced the quality of the score images and made visual recognition of the numbers difficult.

The number identification protocol used was similar to that described in Example 2, including the use of pseudo Zernike moments in feature extraction and application of the similarity measures and fusion rules described above. Table 12 shows the results of the consensus of identification for the defaced numbers on the motorcycle fork. Shown in this table are the target reference library numbers that were matched to the score images of each of the defaced areas. Comparing these results to the known numbers from the engine block, it can be seen that the defaced serial numbers were accurately identified.

TABLE 12

| | Target Number | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 5 | 2 | 5 | 1 | 0 | 0 | 7 | 4 | 1 |
| Majority vote | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Sum | 16 | 16 | 14 | 14 | 14 | 16 | 22 | 20 | 18 |

While certain embodiments of the disclosed subject matter have been described using specific terms, such description is for illustrative purposes only, and it is to be understood that changes and variations may be made without departing from the spirit or scope of the subject matter.

What is claimed is:

**1**. A computer-implemented non-destructive method for identifying a defaced mark in a metal surface comprising:

obtaining a plurality of infrared thermal images of a defaced area on a metal surface according to a lock-in thermal imaging technique;

developing, by a computing system comprising one or more computing devices, a plurality of input images from the plurality of infrared thermal images, the input images comprising phase images, amplitude images or a combination thereof;

developing, by the computing system, a plurality of score images from the plurality of input images, each score image being a reconstruction into an image of a single principal component;

applying, by the computing system, a plurality of similarity measures to one or more of the plurality of score images and to each of a plurality of reference images to obtain a plurality of similarity values for each of a plurality of possible identities of the defaced mark; and

assigning, by the computing system, an identity to the defaced mark based upon the similarity values.